National Institute of Standards and Technology

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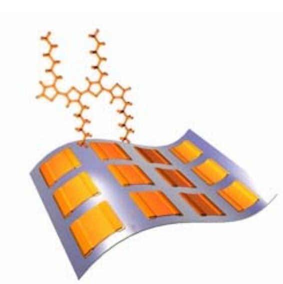
NIST

A United States Measurement System Workshop

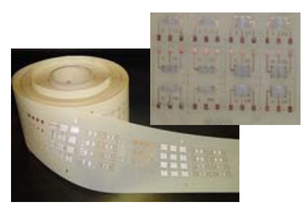
# Flexible, Large-Area Electronics and Photonics

March 6-7, 2006

NIST Advanced Measurement Laboratory
C103-106
Gaithersburg, MD



DARPA



## Large-Area, Flexible Electronics and Photonics

A technology area poised for significant growth is flexible, large-area electronics and photonics. An exciting array of new devices and applications are now possible with materials amenable to incorporation on flexible substrates via low cost, high volume manufacturing. However, the systematic development of flexible, large area electronics is difficult because of the enormous range of potential materials and manufacturing methods. The future growth of this technology may be accelerated through the development of new diagnostic probes, tools, standards, and measurement protocols.

## Objectives

Bring together representatives from industry, government, and academia engaged in the research and development of flexible, large-area electronics and photonics to achieve the following goals.

- Assess the measurement and standards infrastructure available to address technological challenges for this technology.
- Identify significant gaps in the measurement and standards infrastructure that must be closed.
- Document "Measurement Needs" that can address significant technical barriers to innovation and growth of this technology.

## The United States Measurement System

NIST is leading an effort to document future needs for the United States Measurement System (USMS), the complex of all methods, instruments, entities, institutions, and standards involved in measurements of products and processes of significance to the economy, security, and quality of life. Now more than ever, there is a need to create a comprehensive mechanism to anticipate needed measurement infrastructure and to make informed strategic choices to achieve the greatest impact.

## Organizing Committee

Frank Barros, Dean DeLongchamp, David Gundlach, Eric Lin, Jan Obrzut, Robert Reuss (DARPA), Curt Richter, Lee Richter, Michael Schen, Roger Van Zee

**Program Agenda**

**Day 1: March 6, 2006**

| | |
|---|---|
| 8:00 am | Arrival and Coffee |
| 8:30 am | Welcome – The USMS System<br>**Dennis Swyt (Director, USMS Project, NIST)** |
| 8:45 am | “Electronics Anywhere”<br>**Thomas Jackson** (Pennsylvania State University) |
| 9:30 am | “Polymer transistors and TFT backplanes”<br>**Robert Street** (Xerox PARC) |
| 10:15 am | Break |
| 10:30 am | “Crossing the Chasm: Commercializing Printed Electronics”<br>**Dan Gamota** (Motorola) |
| 11:00 am | “RFID: Roll/Roll Processing of Silicon-based Microelectronics”<br>**Paul Drzaic** (Alien Technology) |
| 11:30 am | “The Center for Advanced Microelectronic Manufacturing”<br>**Mark Poliks** (CAMM) |
| 12:00 pm | “Polarization Effects at Organic Semiconductor Interfaces”<br>**Howard Katz** (Johns Hopkins) |
| 12:30 pm | Lunch – Box Lunch, AML |
| 1:45 pm | **Panel Discussion Goals** |
| 2:00 pm | **Discussion – Materials**<br>Moderator: Dean DeLongchamp (NIST)<br>Panel: Howard Katz, Antonio Facchetti, Theo Siegrist |
| 3:00 pm | **Discussion – Devices / Circuits**<br>Moderator: David Gundlach (NIST)<br>Panel: Robert Street, Thomas Jackson, Geoffrey Nunes |
| 4:00 pm | **Discussion – Manufacturing**<br>Moderator: Michael Schen (NIST)<br>Panel: Daniel Gamota, Paul Drzaic, Mark Poliks |
| 5:00 pm | Break and Adjourn |
| 6:00 pm | Dinner – O’Donnell’s Restaurant (Kentlands) |

**Day 2: March 7, 2006**

| | |
|---|---|
| 8:30 am | Arrival and Coffee |
| 9:00 am | NIST Program in Flexible, Organic Electronics<br>**Eric Lin (NIST)** |
| 9:30 am | Breakout session into three groups<br>Consolidate Measurement Needs in Materials, Devices and Circuits, and Manufacturing |
| 10:30 am | Break |
| 11:00 am | Review and Validate Measurement Needs |
| 11:30 am | Concluding Remarks |
| 11:45 am | Box Lunch, AML and Adjourn |

**Example "Measurement Need" Document with Cues**

**Technology at Issue:** Large-Area, Flexible Electronics

**Submitter**: Jane Researcher, Company Affiliation

**Technological Innovation at Stake:** [What the specific technological change, i.e. new technology, that is being anticipated, considered, or attempted, by whom, in what field, firm, sector to what end?] Pharmas anticipate the use of molecular assembly for their manufacture of Z-type nanoparticle drug delivery systems; early-adopters in construction industry have begun using GPS-guided robotic graders

**Economic Significance of Innovation: [**What costs will be incurred if innovation inhibited. What is the return on investment for the implementation of the innovation? Some examples might be quantifications of cost savings, product development time, acceleration of innovation that opens a lucrative window of opportunity…] Acceleration of process time enables a cost reduction to industry, and because of the cost competitive nature of the industry, the cost reduction will be passed to the consumer. This will also enable the ability to produce more targeted drugs in smaller batches…

**Technical Barrier to the Innovation:** [Why can't the innovation be reasonably implemented now or when desired? What technical barrier is in the way?] The basic phenomenon of self-assembling in this particular class of macromolecules is only partially understood with unpredictable variations of behavior occurring; absence of technical data on performance of materials in cantilevered MEMs devices inhibiting development of desired new type of sensor; uncertainty on parts of customers on unverified capabilities of competing types of first generation laser-mapping-guidance systems

**Stage of Innovation Where Barrier Appears:** (R&D, Production, Marketing, End Use) [choose one]

**Measurement-Problem Part of Technical Barrier:** The investigation of the not-well-understood interac-tions of constituents in self-assembling macromolecules requires time- and spatial-resolutions of measur-ing instruments beyond current SOA; there is an absence of a trustworthy reference measurement protocol for evaluation of performance the new-generation laser-mapping-guidance systems

**Potential Solutions to the Problem:** R&D to find practical way to finesse the capabilities of current measurement instrumentation; Development and commercial introduction of new class of instruments;

**Potential Providers of Solution:** [please be as specific as possible] Sector X, Y; Instrument Makers X, Y; consortium industrial firms, University X,Y, Z, NSF, Fed Agency

**Role for Government, if Any:** [What Government-appropriate work might be feasible?] None, i.e. no role for Government; instrumentation development (be more specific); design, develop, or deliver meas-urement data, standard; facilitate cooperation-collaboration among firms.

**If a Government Role, Why Industry Says It Can't/Won't Pay for That Part of Solution:** [Please explain why it is inappropriate for industry to pay for this work on its own. Industry quotes might support your response] nonappropriability of profits (i.e. inability of a single investor in the solution to recover that original investment); extreme high technical risk; need for cross-cutting team to produce a useable solution; as well as specific issues for the public good (requires explanation), such as the ability to share the solution openly.

**Example: Completed MN Document**
(Draft only, not for attribution or distribution)

Kalman Migler 3/2/2006 Discipline: Materials Science and Engineering

**Technology** Carbon Nanotube Materials

**Technological Innovation at Stake:** Nanotube materials possess an extraordinary combination of materials properties: strength, thermal conductivity and electronic properties. Successful incorporation of nanotube materials into a broad-range of critical technologies including fuel cells, semi-conductors, sensors, fibers, displays, and composite materials will yield revolutionary advances in product performance. As one example, in fuel cell applications, the nanometer scale and novel chemical characteristics of SWNTs give them profound advantages as electro-catalyst supports and enable the fabrication of "free standing" fuel cell electrodes considerably more powerful than those currently in use.

**Economic Significance of Innovation:** In the automotive arena alone, OTP projects a $70 billion market at stake for vehicles powered by fuel cells. FreedomCAR describes the necessary performance/cost requirements of the fuel cells that include 60% efficiency at a price of $30/kW. Nanotube based fuel-cells are leading contenders to meet these requirements.

**Technical Barrier to the Innovation:** The quality and purity of nanotubes is preventing high-tech applications because they require reliable and consistent materials of a given sub-type. All nanotube materials are comprised of dozens of subtypes of nanotubes that differ in length, diameter and electronic properties. There are no accepted methods of characterizing nanotube samples for these parameters, hindering trade and, there is no technique that allows a manufacturer to isolate and identify the appropriate type of nanotube needed for a given product.

**Stage of Innovation At Which Barrier Appears** (R&D)

**Measurement-Problem Part of Technical Barrier:** In order to for a manufacturer to provide nanotube materials of specified length, diameter and chirality, they need quantitative measurement techniques to characterize their samples, so that techniques to sort them by these characteristics can be developed.

**Potential Solutions to Problem:** Development of solution based chromatography to sort the nanotubes, coupled with quantitative spectroscopic methodology to efficiently determine the nanotube type.

**Potential Providers of Solutions:** The consensus of an industrial, government and academic workshop was that NIST must provide these solutions. Rice University is funded to develop a method to manufacture nanotubes of pre-specified type.

**Role for NIST if Any:** To develop a comprehensive metrology program focused on solutions for the three critical interrelated issues facing carbon nanotubes applications: quality, characterization, and alignment. NIST will transfer these solutions to industry, academia and voluntary standards setting bodies.

**If a Government Role, Why Industry Says It Can't/Won't Pay for That Part of Solution:** There are numerous industries focused on applications development for their particular sectors, but the quality and sorting issues are too broad and high-risk to be attacked by any single sector

**Example: Completed MN Document**
(Draft only, not for attribution or distribution)

**Technology at Issue:** Sub-50 nm Lithography **Submitter(s):** Vivek M. Prabhu

**Technological Innovation at Stake:** The production of smaller device structures for the continued increase in cost to performance of integrated circuits; 20 nm by 2009 and 10 nm by 2013. Continued progress in the semiconductor industry depends upon the ability to develop materials capable of manufacturing designed patterns with sub-50 nm dimensions with sufficient dimensional control and resolution.

**Economic Significance of Innovation:** The semiconductor industry is a significant driving force in the U.S. economy and the lithography process is a major part of the cost of manufacturing integrated circuits. Typically, at least four layers are critical layers requiring the most advanced lithographic tool available. Novel device structures might also introduce several additional critical layers. Lithography, including masks and resist, and associated metrology currently comprises 30–40% of the entire cost of semiconductor manufacturing.

**Technical Barrier to the Innovation:** It is unknown whether apparent limitations in the patterning ability of current materials for industrial nanofabrication, chemically amplified photoresists, are intrinsic resolu-tion limits of the material (line-edge roughness of 4 nm) or can be improved with better optics and process control. Maintaining the rapid pace of shrinking dimensions requires significant improvements in optical projection lithography technology or the development of alternative, next generation lithography technolo-gies.

**Stage of Innovation Where Barrier Appears** [Choose one]: R&D

**Measurement-Problem Part of Technical Barrier:** At nanoscale dimensions, the details of local materials properties and physico-chemical processes affect the resolution of the lithographic process. Current measurement methods do not provide the spatial resolution or chemically specific information needed to carefully probe process parameters that limit the patterning resolution and to inform potential solutions. There are too many variables to depend upon trial-and-error improvements.

**Potential Solutions to Measurement Problem:** Integrated measurements that can provide unique informa-tion about complex physico–chemical processes used in advanced chemically amplified photoresists. Methods include x-ray and neu-tron reflectivity (XR, NR), small angle neutron scattering (SANS), near edge x-ray absorption fine structure (NEXAFS) spectroscopy, combinatorial methods, and quartz crystal microbalance (QCM) measurements. With this information, better physical/chemical models can be developed to predict three-dimensional resist geometries after development and process windows, including effects such as line-edge roughness.

**Potential Providers of Solutions:** Advanced measurement methods

**What is the role for Government, if Any?:** Government agencies can provide advanced measurement methods such as synchrotron and neutron facilities (scattering, reflectivity, and spectroscopy) and support needed to understand the limitations and potential of lithography materials and processes.

**If There is a Government Role, Why Industry Says It Can't/Won't Pay for That Part of Solution:** The semiconductor industry is investing towards the solution of these industry-wide problems, but it is beyond the scope and cost for any company to develop separately.

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**Technology at Issue:**

**Submitter(s):**

**Technological Innovation at Stake:**

**Economic Significance of Innovation:**

**Technical Barrier to the Innovation:**

**Stage of Innovation Where Barrier Appears [Choose one]:** (R&D, Production, Marketplace, End Use)

**Measurement-Problem Part of Technical Barrier:**

**Potential Solutions to Measurement Problem:**

**Potential Providers of Solutions:**

**What is the role for Government, if Any?:**

**If There is a Government Role, Why Industry Says It Can’t/Won’t Pay for That Part of Solution:**

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**Technology at Issue:**

**Submitter(s):**

**Technological Innovation at Stake:**

**Economic Significance of Innovation:**

**Technical Barrier to the Innovation:**

**Stage of Innovation Where Barrier Appears [Choose one]:** (R&D, Production, Marketplace, End Use)

**Measurement-Problem Part of Technical Barrier:**

**Potential Solutions to Measurement Problem:**

**Potential Providers of Solutions:**

**What is the role for Government, if Any?:**

**If There is a Government Role, Why Industry Says It Can't/Won't Pay for That Part of Solution:**

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**Submitter(s):**

**Technological Innovation at Stake:**

**Economic Significance of Innovation:**

**Technical Barrier to the Innovation:**

**Stage of Innovation Where Barrier Appears [Choose one]:** (R&D, Production, Marketplace, End Use)

**Measurement-Problem Part of Technical Barrier:**

**Potential Solutions to Measurement Problem:**

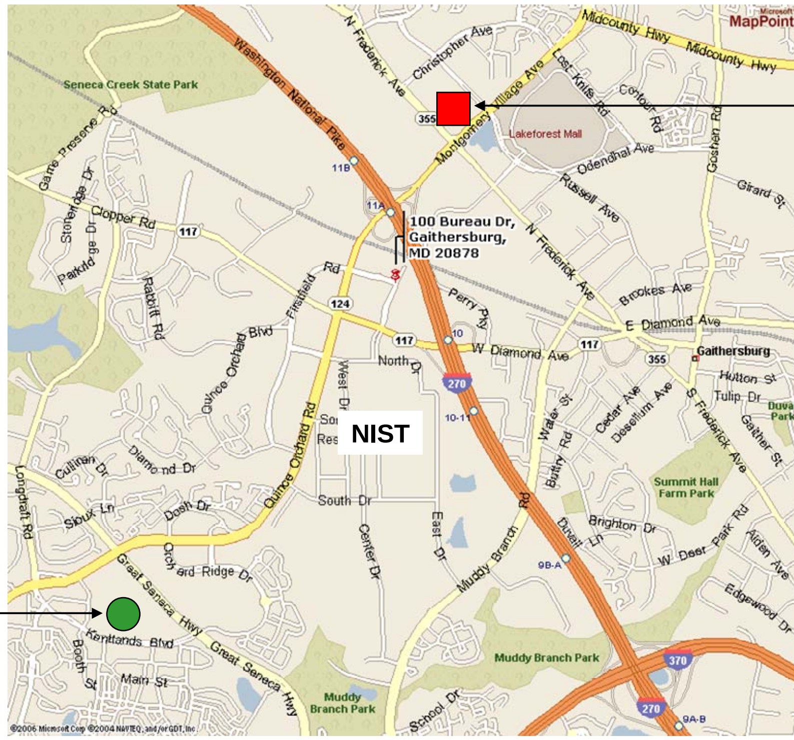
**Potential Providers of Solutions:**

**What is the role for Government, if Any?:**

**If There is a Government Role, Why Industry Says It Can’t/Won’t Pay for That Part of Solution:**

## Map with Locations

Holiday Inn
2 Montgomery Village Ave.,
Gaithersburg, Md.. 20879
(301) 948-8900




O'Donnell's Restaurant
311 Kentlands Blvd,
Gaithersburg, MD
(301) 519-1650

**Notes**

## Notes

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